A PRINTED WIRE BOARD AND ASSOCIATED MOBILE TERMINAL

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is related to multi-layer printed wire boards (PWBs), such as for use in electronic devices, and more particularly to multi-layer PWBs for use in mobile terminals.

Description of Related Art

Multi-layer printed wire boards (PWBs) are the platform on which complex electronic components such as integrated circuits and a number of passive components, such as capacitors and resistors, are mounted. PWBs serve as a structural foundation and a hub for electrical connections for a variety of electronic devices. Specifically, multi-layer PWBs allow for a plurality of interconnected conductive layers to be packed into a compact space, and as such, they are useful in manufacturing portable electronic devices, including mobile terminals. Multi-layer PWBs must provide not only a compact hub for electrical connections but also a robust mechanical and electrical connection between the electronic components that make up a given device. Of particular interest in portable electronic devices is increasing the drop reliability of the PWB, or the ability of the PWB to maintain a physical and electrical connection between electronic components even after being subjected to the mechanical shock from a drop onto a hard surface, as users of portable electronic devices are unfortunately prone to do.

Originally, drop reliability of multi-layer PWBs was increased by simply increasing the overall thickness and stiffness of the multi-layer PWB. While this solution is effective in securing the mechanical and electrical connections between components on the PWB upon a mechanical shock, it has the negative result of making the miniaturization of the PWB more difficult. In this regard, portable electronic devices are continually being made smaller and, as such, it is desirable that the constituent components, such as the PWB, be similarly made smaller. In addition, thicker and stiffer multi-layer PWBs often suffer from decreased reliability under thermal load, since solder reliability and electrical connectivity under varying thermal load is decreased as the

thickness of the multi-layer PWB is increased. This decreased reliability is due in part to the inability of the thick and stiff PWB to flex and conform to the subtly changing sizes and shapes of electrical components and their solder connections during thermal load cycles.

One conventional PWB that is utilized in mobile telephones has eight copper layers separated by dielectric layers or resin coated copper layers. Beginning from one surface of the PWB, a first outermost copper layer is disposed upon a resin coated copper layer which, in turn, is disposed upon a second copper layer. The second copper layer is disposed on a first dielectric layer which, in turn, is disposed on a third copper layer. The third copper layer is disposed upon a second dielectric layer which, in turn, is disposed upon a fourth copper layer. The fourth copper layer is disposed upon a third dielectric layer. The third dielectric layer is centrally located within the PWB and the PWB structure is effectively mirrored about the third dielectric layer. As such, the third dielectric layer is disposed upon a fifth copper layer which, in turn, is disposed upon a fourth dielectric layer. The fourth dielectric layer is disposed upon a sixth copper layer which, in turn, is disposed upon a fifth dielectric layer. The fifth dielectric layer is disposed upon a seventh copper layer which, in turn, is disposed upon a second resin coated copper layer. The second resin coated copper layer is disposed upon an eighth copper layer which forms the opposed surface of the PWB.

Typically, the dielectric layers are formed of a FR-4 glass fiber/epoxy material, such as an FR-4 glass fiber/epoxy material bearing the designation MCL-E-679F provided by Hitachi, Ltd. Additionally, the resin coated copper layers may be formed of a material bearing the designation MCF-6000E that is also provided by Hitachi, Ltd.

The copper layers may be electrically connected by means of vias through the resin coated copper layers and/or the dielectric layers. Based upon the various electrical connections and the components mounted upon the first and eighth copper layers, the PWB can therefore provide the desired functionality.

While this conventional PWB generally performs as desired, this PWB is thicker and stiffer than desired. In this regard, the first, second, seventh and eighth copper layers of a conventional PWB have a thickness between 25 um and 50 um with a nominal thickness of 35 um, while the third, fourth, fifth and sixth copper layers have a thickness

of between 12 um and 19 um with a nominal thickness of 17 um. Additionally, the resin coated copper layers of a conventional PWB have a thickness of between 50 um and 70 um with a nominal thickness of 60 um, while each dielectric layer is quite thick and contributes substantially to the overall thickness of the PWB with a thickness between 125 um and 175 um and a nominal thickness of 150 um. In this regard, the thickness of the PWB contributes to the overall size of the mobile terminal and it would therefore be desirable to reduce the size of the PWB and, in turn, the size of the mobile terminal. Additionally, this conventional PWB has not performed as desired in terms of drop reliability. In other words, the PWB has a tendency to no longer function properly after a lesser number of drops than is desired. Since consumers are demanding increased reliability in portable electronic products, it is also desirable to improve the drop reliability of the PWB.

Therefore, it would be advantageous to have an optimized multi-layer PWB structure with an increased mechanical strength and drop reliability, while still maintaining a thin and flexible structure that is compact and less susceptible to connection failure under cyclical thermal loads.

BRIEF SUMMARY OF THE INVENTION

The present invention addresses the above needs by providing an improved PWB multi-layer structure and an associated mobile terminal, that has increased drop reliability and mechanical strength while maintaining an overall thin cross section that is able to withstand cyclical thermal loads without suffering premature failure in its associated electrical connections. The improved PWB structure is composed of a plurality of conductive layers interspersed with insulative layers and selectively-placed insulative-coated conductive layers in which the thicknesses of the respective layers have been optimized to provide a thin overall PWB structure that is both structurally sound when subjected to drop tests, and electrically sound when subjected to cyclical thermal loading.

In one embodiment, the multi-layer PWB structure of the present invention includes a first conductive layer having a thickness between 25μ and 50μ. The first conductive layer is disposed upon a first insulative-coated conductive layer that has a thickness between 50μ and 70μ. A second conductive layer is disposed upon the first

insulative-coated conductive layer and has a thickness between 25μ and 50μ. The second conductive layer is disposed upon a first insulative layer which, in turn, is disposed upon a third conductive layer. The third conductive layer is disposed upon a second insulative layer which, in turn, is disposed upon a fourth conductive layer. The fourth conductive layer is, in turn, disposed upon a third insulative layer. In order to provide the desired improvements in drop reliability and electrically conductivity, the first, second and third insulative layers each have a respective thickness between 50μ and 100μ, and the third and fourth conductive layers each have a respective thickness of between 12μ and 19μ. According to one advantageous embodiment, the first and second conductive layers have a respective nominal thickness of 35μ, the first insulative-coated conductive layer has a nominal thickness of 60μ, each insulative layer has a respective nominal thickness of 75μ and the third and fourth conductive layers have a respective nominal thickness of 17μ.

In one embodiment, the conductive layers are formed of copper and the insulative-coated conductive layer is formed of a resin-coated copper layer. In addition, each insulative layer may comprise a dielectric layer, typically formed of glass fibers in an epoxy matrix. In order to provide the desired electrical connectivity, each insulative-coated conductive layer may define one or more vias between the conductive layers that are disposed on opposite sides thereof. Thus, the respective pair of conductive layers separated by the insulative-coated conductive layer are in electrical communication through the one or more vias defined by the insulative-coated conductive layer. The multi-layer PWB structure may be a symmetrical structure about the third insulative layer. As such, in one embodiment, the third insulative layer is disposed upon a fifth conductive layer which, in turn, is disposed upon a fourth insulative layer. The fourth insulative layer of this embodiment is disposed upon a sixth conductive layer which, in turn, is disposed upon a fifth insulative layer. The fifth insulative layer is disposed upon a seventh conductive layer which, in turn, is disposed upon a second insulative-coated conductive layer. The second insulative-coated conductive layer is disposed upon an eighth conductive layer. In this embodiment, the fifth and sixth conductive layers may each have a respective thickness of between 12μ and 19μ and the fourth and fifth insulative layers may each have a thickness of between 50μ and 100μ. In addition, the seventh and eighth conductive layers may each have a thickness of between 25μ and 50μ

and the second insulative coated and conductive layer may have a thickness between 50μ and 70μ in order to optimize the drop reliability and electrical conductivity of the multi-layer PWB of this embodiment of the present invention.

In addition to the multi-layer PWB, a mobile terminal incorporating a multi-layer PWB is also provided according to another aspect of the present invention. The multi-layer PWB and, correspondingly, the mobile terminal of the present invention have many advantages. For example, the PWB structure is optimized to provide a mechanically stable connection between electrical components without the need for an excessively thick or stiff PWB. In addition, the PWB structure is composed of a selection of materials of layer thicknesses that provide a reliable electrical connection between electrical components even under cyclical thermal loads. The combination of thin cross-section and robust mechanical and thermal properties make the PWB of the present invention suited for use in many electronic devices, and particularly well-suited for miniaturized mobile electronic devices, such as mobile terminals including mobile telephones, PDA's, pagers, and the like.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is a partially-exploded view of a mobile terminal including a multi-layer PWB of the present invention;

Figure 2 is a side view of an embodiment of a PWB multi-layer structure of the present invention showing relative thicknesses of the adjacent layers; and

Figure 3 is a table showing the layer thicknesses and tolerances for layer thickness for one embodiment of a multi-layer PWB structure of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present inventions now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these

embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

A mobile terminal **300**, such as a mobile telephone, in accordance with one aspect of the present invention, is shown partially disassembled in Figure 1. In particular, the front cover **500** of the mobile terminal has been removed to illustrate some of the internal components of the mobile terminal. In this regard, the mobile terminal includes a multi-layer PWB **100** that is shown to be disposed in a housing **400**. The multi-layer PWB **100** carries and electrically interconnects a number of electronic components **200**, such as integrated circuit(s), microprocessor(s) and passive components, such as capacitors, inductors and resistors. Among these electronic components, the mobile terminal **300** may include and the multi-layer PWB **100** may carry and electrically connect a transmitter and a receiver, sometimes configured as a transceiver, for transmitting and receiving signals, respectively, via a wireless communications system. Although not shown in Figure 1, the mobile terminal generally includes an EMI shield that effectively shields the plurality of electronic components **200** that are connected to the multi-layer PWB **100**, as well as the PWB itself, from electromagnetic interference.

The multi-layer PWB **100** described herein may be used in any electronic device, but is preferably used in a mobile terminal **300**. The multi-layer PWB is preferred for such mobile terminals due to its thin cross section, low weight, and improved mechanical soundness as compared to other PWBs which generally exhibit connection failures after a fewer number of drops onto a hard surface. Generally, the mobile terminal **300** discussed herein for use of the multi-layer PWB **100** is a mobile telephone, but such descriptions are illustrative of only one type of mobile terminal that would benefit from the present invention and, therefore, should not be taken to limit the scope of the present invention. For example, other types of mobile terminals, such as portable digital assistants (PDAs), pagers, laptop computers and other types of voice and text communications systems, can readily employ the present invention. Moreover, the system and method of the present invention will be primarily described in conjunction with mobile communications applications. But the system and method of the present invention can be utilized in conjunction with a variety of other applications, both in the mobile communications industries and outside of the mobile communications industries.

Figure 2 shows a cross-section of the layers which make up the PWB **100** of one embodiment of the present invention. The PWB of this embodiment includes a third insulative layer **108** that is typically comprised of a dielectric laminate and is sandwiched between the fourth conductive layer **107** and the fifth conductive layer **109**. The three layers are further sandwiched between the second insulative layer **106** and the fourth insulative layer **110**, both of which are also typically comprised of dielectric laminates. A third conductive layer **105** is typically disposed upon the second insulative layer **106**, opposite the fourth conductive layer **107**, and a sixth conductive layer **111** is generally disposed upon the fourth insulative layer **110**, opposite the fifth conductive layer **109**. The PWB **100** of the illustrated embodiment also includes a first insulative layer **104** disposed upon the third conductive layer **105**, opposite the second insulative layer **106**, and a fifth insulative layer **112** disposed upon the sixth conductive layer **111**, opposite the fourth insulative layer **110**. As before, the first and fifth insulative layers **104, 112** are typically comprised of dielectric laminates.

A respective interconnect structure comprised of a pair of conductive layers disposed on opposite surfaces of a insulative-coated conductive layer is disposed upon each of the first and fifth insulative layers **104, 112**, opposite the third and sixth conductive layers **105, 111**, respectively. In this regard, a first interconnect structure comprised of first and second conductive layers **101, 103** positioned on opposed surfaces of a first insulative-coated conductive layer **102** may be disposed upon the first insulative layer **104**, while a second interconnect structure comprised of seventh and eighth conductive layers **113, 115** positioned on opposed surfaces of a second insulative-coated conductive layer **114** may be disposed on the fifth insulative layer **112**.

As used herein, reference to one layer being disposed upon another layer is not intended to connote a particular positional relationship, such as one layer being "on" another layer, and is also not intended to connote that one layer is immediately adjacent another layer. Instead, the layers may be separated by one or more intervening layers.

As described, the PWB **100** of the illustrated embodiment is symmetrical relative to the third insulative layer **108** with a first set of layers between and including the first conductive layer **101** and the third insulative layer **108** being identical in material and thickness to a second set of layers between and including the third insulative layer **108**

and the eight conductive layer **115**. If this symmetrical structure is not necessary, the PWB **100** of another embodiment need only include one set of layers in order to further thin the PWB **100**.

In one embodiment of the multi-layer PWB structure **100** described above, each insulative layer **104, 106, 108, 110, 112** is comprised of the same type of dielectric laminate, namely, an FR-4 material comprised of glass fibers in an epoxy matrix. For example, the insulative layers may be comprised of an FR-4 glass/epoxy material provided by Matsushita Electric Industrial Company, Ltd. (hereinafter Matsushita) bearing product number 1766. Additionally, the insulative-coated conductive layers **102, 114** may be formed of resin coated copper, i.e., RCCu, such as that provided by Matsushita bearing product number R0880. Further, the conductive layers **101, 103, 105, 107, 109, 111, 113, 115** may be formed of the same material, such as copper.

The particular thickness of each layer including both its nominal thickness and its tolerance is significant to provide a relatively thin PWB **100** that has improved drop reliability and that mains electrical connectivity during thermal cycling. In this regard, the preferred dimensions and tolerances for one advantageous embodiment of the present invention are presented in the table of FIG. 3. The preferred thickness dimensions and tolerances for each layer in this embodiment are as follows: (1) all insulative layers **104, 106, 108, 110, 112**: 75um +/- 25 um, (2) third, fourth, fifth, and sixth copper conductive layers **105, 107, 109, 111**: 17 um +2/-5 um, (3) first, second, seventh and eighth conductive layers **101, 103, 113, 115**: 35 um +15/-10 um, and (4) all insulative-coated conductive layers **102, 114**: 60um +/- 10um. As such, the layers of the inventive PWB **100** are thinner than a conventional PWB, with the particular combination of layer thicknesses chosen to optimize drop reliability and electrical connectivity during thermal cycling while thinning the PWB.

The conductive layers of each interconnect structure are generally electrically connected in a predefined manner through vias defined by the insulative-coated conductive layers **102, 114**. In this regard, the vias may be defined, such as by micro-drilling, between the respective conductive layers and the sidewalls of the vias may be electro-plated with a conductive material, such as copper, to establish an electrical connection between the conductive layers. Thus, the first and second conductive layers

101, 103 may be selectively connected by means of plated-through vias defined by the first insulative-coated conductive layer **102**. Similarly, the seventh and eighth **113, 115** conductive layers may be selectively connected by means of plated-through vias defined by the second insulative-coated conductive layer **114**. Likewise, the third, fourth, fifth and sixth conductive layers **105, 107, 109, 111** may be selectively interconnected to one another and/or to the first, second, seventh and eighth conductive layers by vias defined through the respective insulative layers as known to those skilled in the art.

As noted above, the insulative layers that contribute substantially to the overall thickness of the PWB **100** are much thinner, such as by 50%, than corresponding insulative layers of a conventional PWB. In addition, the third, fourth, fifth and sixth conductive layers **105, 107, 109, 111** are advantageously thinner, such as by about 50%, than the first, second, seventh and eighth layers **106, 108, 113, 115** that comprise respective interconnect structures. Thus, the thinner insulative layers and the interior conductive layers facilitate the thinning and flexibility of the PWB **100**, while the thicker conductive layers of the interconnect structures provide the desired reliability in electrical connectivity.

The multi-layer PWB **100** of the present invention can be constructed with conventional techniques of printed wire board construction. For example, the conductive layers may be electrodeposited as a thin foil upon a respective insulative layer or insulative-coated conductive layer. This electrodeposited foil may then be marked and chemically etched to the desired pattern as known to those skilled in the art. Additionally, once the layers have been appropriately stacked, the layers may be consolidated or integrated by press lamination or the like. Thereafter, the resulting PWB structure **100** can be cut into any shape to fit properly within the electronic device, such as a mobile terminal **300** for which it was designed.

By properly designing the thickness and composition of the respective layers, the resulting PWB **100** has improved drop reliability. In this regard, the PWB of the embodiment depicted in Figures 2 and 3 has a drop reliability, as determined by the JEDEC Standard Test Method B 104-A Mechanical Shock Test, that is ten times better than the drop reliability of the conventional PWB described in the background section. In other words, the PWB of Figures 2 and 3 may be dropped ten times more, on average,

than the conventional PWB described in the background section before suffering the same predefined number of defects that is considered to render the PWB non-functional.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.